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FINAL REPORT

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"Mass Flow Velocity Distribution in the Solar Chromosphere"

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A) Introduction

Observations of XUV lines by rocket and satellite experiments (e.g. Doscheck, Feldman, and Bohlin, 1976) indicated that lines formed in the transition region over chromospheric network and cell regions, and coronal holes, exhibited, in some cases, a definite red shift. The observed shifts indicated descending velocities on the order of 10 Km/s. The shifts were interpreted as the descending plasma in the solar atmosphere producing more emission than the ascending plasmas at temperatures between $\sim 7\times10^{4}$ °K and 2×10^{5} °K, and led to the understanding that convection was an important means of energy transport in the transition region.

Since these flows appeared to be predominately into regions of strong magnetic fields, it was felt that the behavior could result from cooling due to local thermal instabilities in coronal material which becomes denser than the surrounding coronal plasma and falls into the chromosphere (Pneuman and Kipp, 1977).

Dere et at (1981) in their analysis of C IV profiles from the NRL HRTS (High Resolution Telescope and Spectrograph) instrument likewise showed stronger red than blue components due to Doppler shifts indicating net downward flows from 2-15 Km/s in the transition region over quiet regions of the sun.

It appeared that with the improved spatial and temporal resolution, the down-flow of material, only partially observed in the past, was much more predominant than previously thought. Such a picture posed an extremely puzzling problem in light of the supposed mass balance that was thought to exist in the solar atmosphere.

Up to this point in time, nothing had been done to interpret the HRTS spectral data from lower regions of the transition region. Therefore, it appeared to be advantageous to investigate such spectral line profiles in an attempt to see whether or not a similar phenomena exists, and if some detail of mass flow could be deduced from the data.

Therefore, a study of chromospheric lines--specifically those of Si-II and Si-III was made using the data from HRTS. The optically thick line profiles such as λ1206 due to Si-III and λ1265 and λ1533 due to Si-II were to be investigated in detail using the techniques of spectrum synthesis in an attempt to model the mass flow velocity distribution in that region of the

APPENDIX

A montage of line profiles from the same portion of the quiet sun region are shown in Figure 2(a), 2(b), 2(c) for three different resonance lines in Si-II and Si-III.

Each scan corresponds to an adjacent region of the sun along the slit of the spectrograph. It should be noted that there is evidence of a shift from the blue to the red. This shift is especially evident in the reversed λ1265 and λ1533 lines of Si-II. The Si-III line at λ1206 is not strongly reversed and thus the evidence of Doppler shifting is not as apparent.

C) Experimental Results

The above mentioned results seem to indicate clear evidence for regions of adjacent upward and downward flow in the lower chromosphere. The data appear to show that convective cells appear to exist in this region just below the transition region.

The actual velocities of the convective flows, of course, cannot be accurately determined since the lines are optically thick in this region.

The experimental results are, therefore, somewhat limited in scope, since a more detailed interpretation must come from spectum synthesis modeling calculations.

D) Modeling Calculations

Our approach in modeling the mass motion of the solar chromosphere involved first assuming a temperature, density and turbulence distribution, and then computing line profiles of the optically thick lines of Si-II and Si-III, that agree with the observations in both shape and absolute intensity.

The model atmosphere used was that of Varnazza, Avrett, and Loeser (1973) or VAL for a quiet sun. This model atmosphere gives reasonable fits to the silicon lines so far as intensities and equivalent widths are concerned for the silicon lines (see Tripp, et al, (1978)).

Athay (1972) has shown that the Doppler displacement of a line profile often gives the illusion of macroturbulence through a large range of depths, whereas in reality only a limited region of the atmosphere is in motion. This is evidenced by the three H-α profiles shown in Figure 3.

In both Case 1 and 2, the line profiles show displacement toward the red wing of the line. It is interesting to note that in Case 2, where essentially none of the line forming layer is in motion, an observer erroneously infers from the line displacement that the entire chromosphere below where $\tau = 1$ and the upper photosphere is moving downward.

Clearly, the use of the standard technique of using the displacement of the line symmetry of a profile will not give correct results. The velocities obtained will be too small and at the wrong depths. Therefore, it appears that one must use the more lengthy method of spectrum synthesis to arrive at a proper interpretation--at least as far as strong lines are concerned.

Hummer and Rybicki (1968) have shown that differential mass motion in the atmosphere may produce a variety of effects upon the line also. For example, in the case of spectral lines that are self-reversed, the relative intensities of the twin peaks are asymmetrical as shown in Figure 4 where they are shifted toward the red. However, the central reversal separating the emission peaks is shifted toward the blue. Thus the effects of velocity gradients may strongly influence the line profile. This was also found by Tripp, et al (1978) to be the case with microturbulence.

Weaker lines, on the other hand, form in layers more nearly of the order of their atmospheric density scale heights, and there is less likelihood of strong velocity gradients occurring within this line forming layer.

The computational method used was patterned after the complete linearization method of Auer and Milhalas (1969) as adapted by Richard Shine of GSFC for a plane-parallel model atmosphere. The program was modified to include a turbulent velocity gradient through the model atmosphere. Such an atmosphere would be a reasonable approximation near sun center.

E) Concluding Note:

NCAR announced that effective October 1, 1980, that all non-NSF users would be charged $0.165/computer resource unit. Only a small amount of money was budgeted for computer time to use a remote job entry terminal to the NCAR computer. It was estimated that approximately $5,000 of computer time was needed. Therefore, the project ground to a halt due to lack of funds.

In early 1981, correspondence was received from NCAR indicating that a previous NASA Grant (NAS8-33113) was exempted from the October 1980 edict. Therefore, a no-cost extension of NAGW - 19 was requested and granted. A limited amount of salary and travel money was still available in the grant to help finance further work.

Additional data reduction was pursued and the radiative transfer program developed for spectrum synthesis was modified to include a turbulence velocity gradient through the model atmosphere. However, there wasn't adequate time to get the program operational and checked out before August 31, 1981 expiration of the computer funding under the previous grant.

Funding from NASA for an additional year to finish the research was requested, but was denied, so the project remains unfinished.

APPENDIX

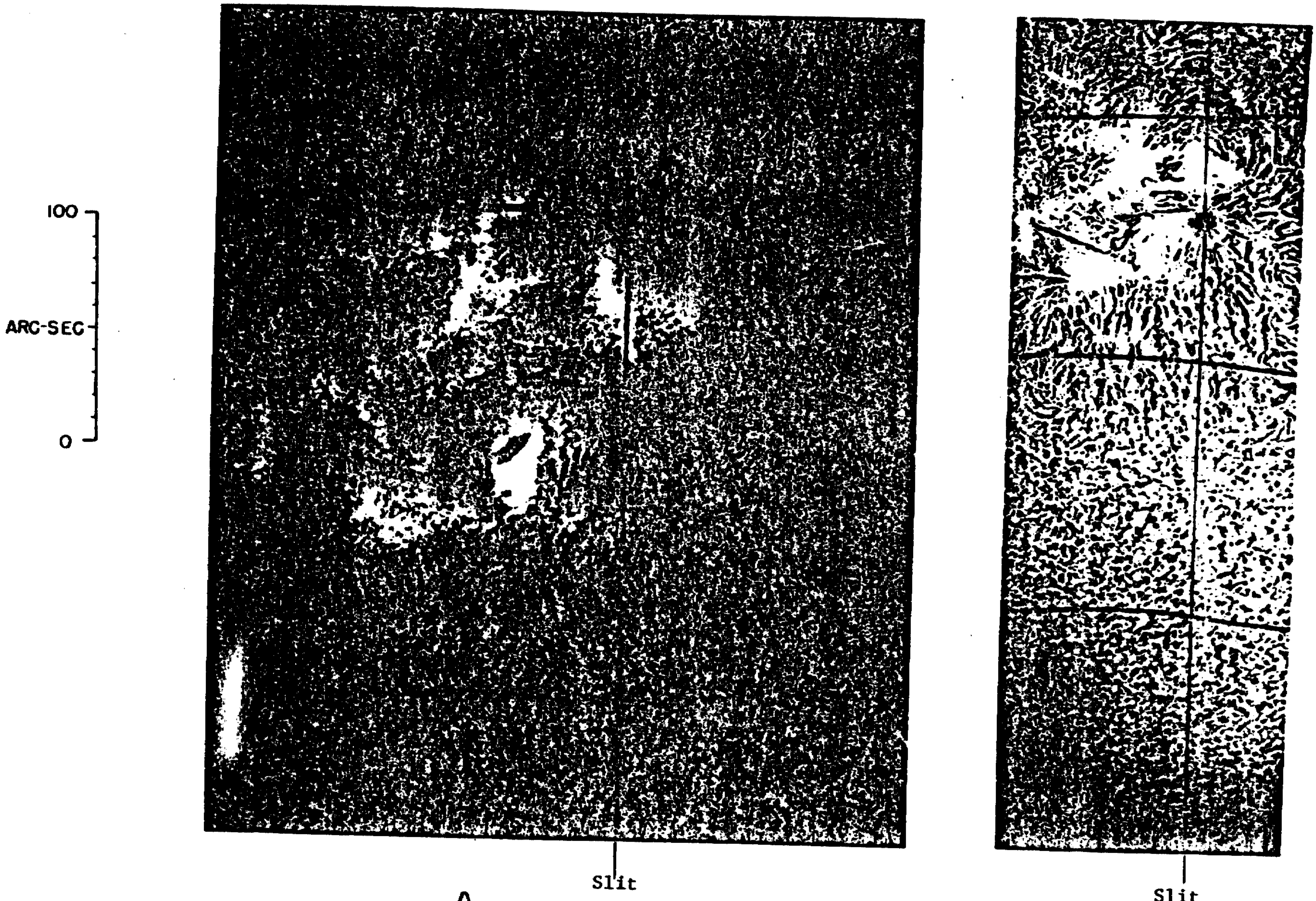

Fig. . 1. H-α photographs.
A) Close-Up view of sunspot region in (B)
B) Solar disk and position of slit

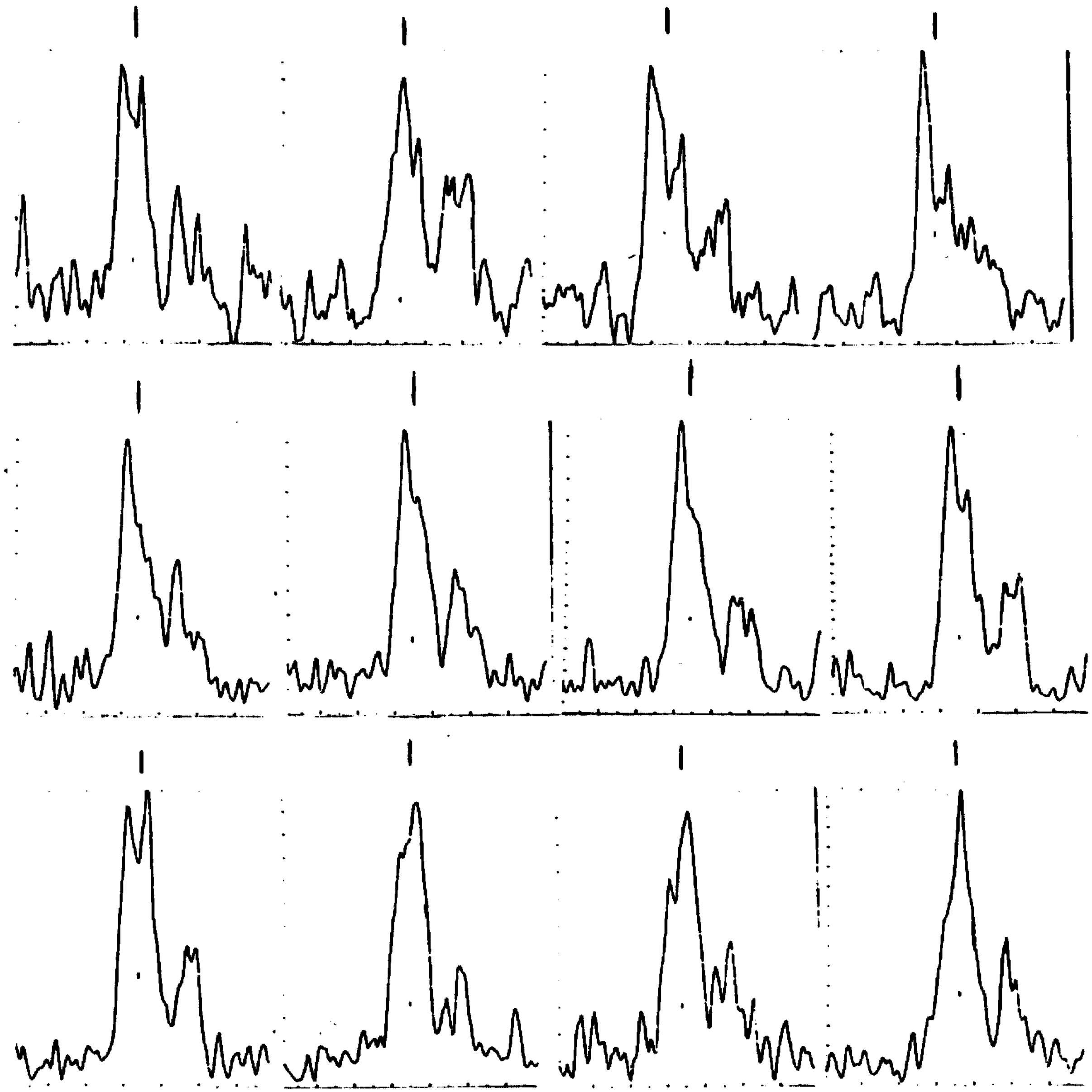

Figure 2(a) - λ1265

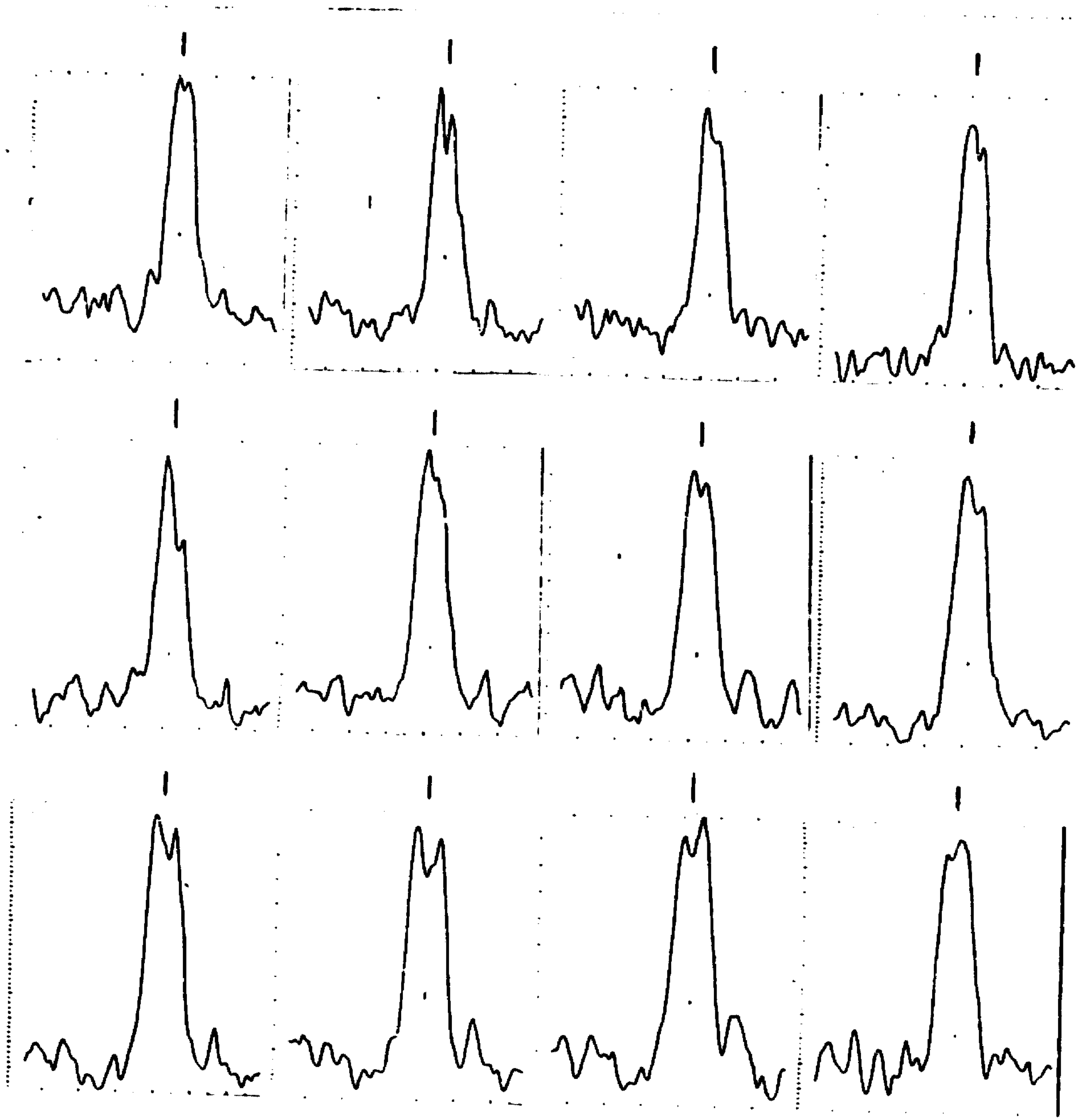

Figure 2(b) - λ1533

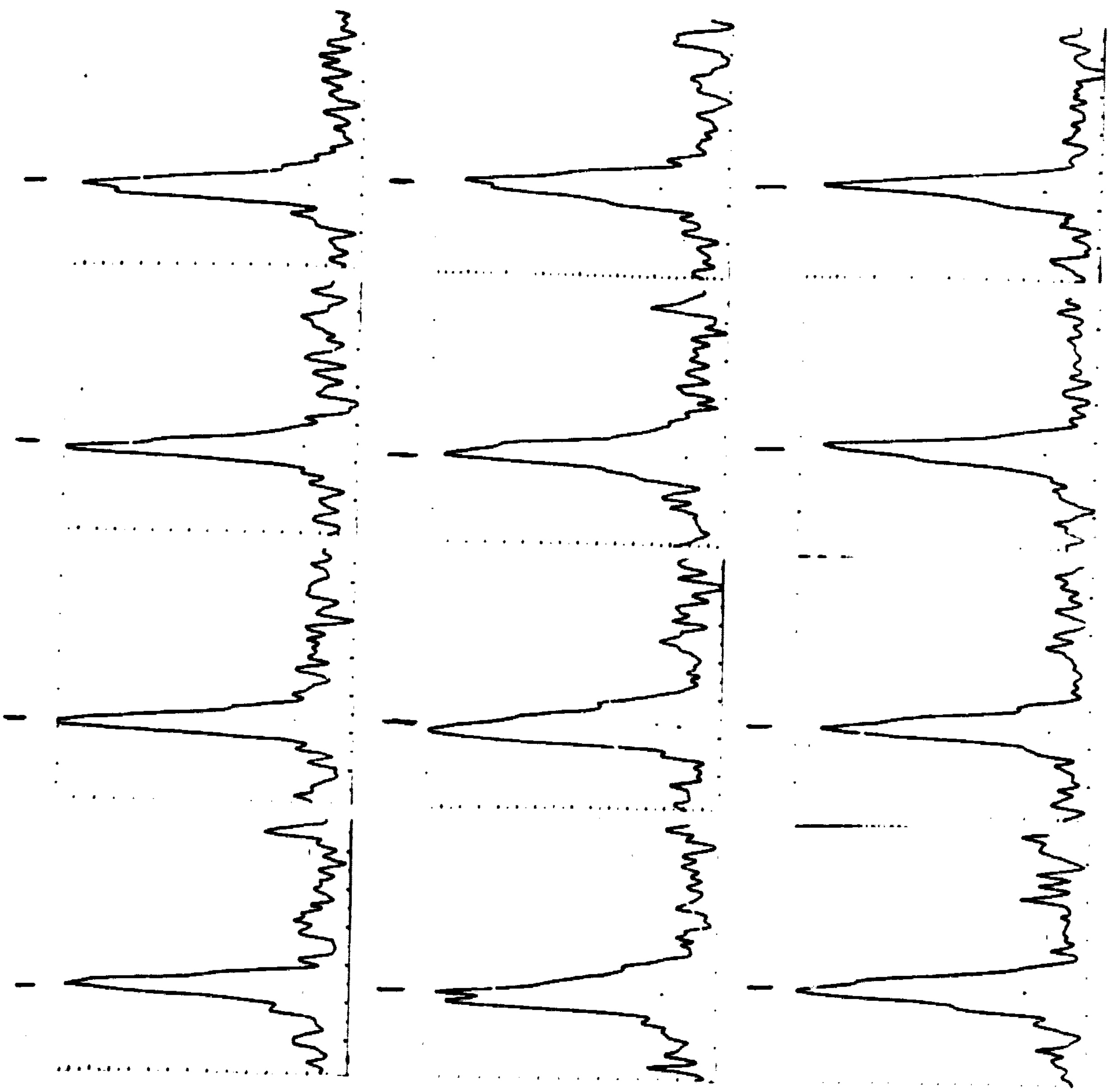

Figure 2(c) - λ1206

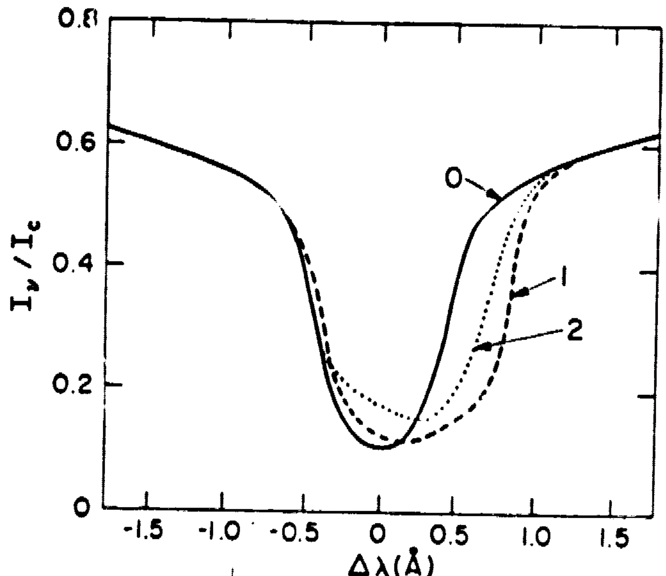

Figure 3. Three Hα profiles computed for

0 - Stationary atmospheres
1 - Downward motion for $1 \leq \tau_0 \leq 100$
2 - Downward motion for $\tau_0 \lesssim 1$

(From Athay (1972)

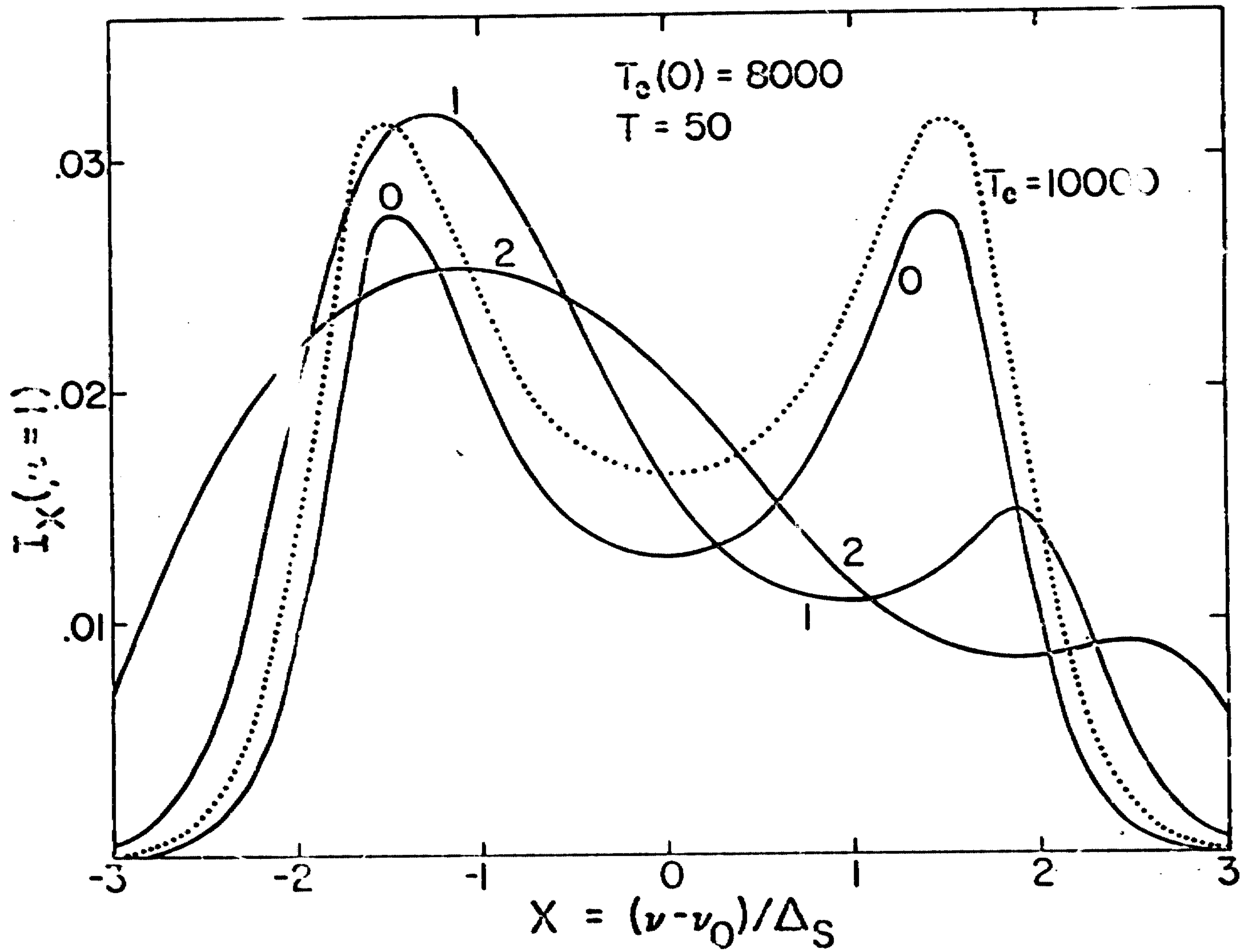

Figure 4 Profiles for a differentially moving atmosphere computed by Hummer and Rybicki (1968).

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